ELECTRODE PROTOTYPING ACTIVITIES IN ANL'S CELL ANALYSIS, MODELING AND PROTOTYPING (CAMP) FACILITY

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Project ID: BAT030

Overview

Timeline

- Start: October 1, 2014
- Finish: September 30, 2023

Budget

- FY22 - $800K
  - 100% DOE-EERE-VTO
- Partners: MERF, EADL, APS, CNM, PTF, universities, and industries

Barriers

- Development of PHEV and EV batteries that meet or exceed DOE/USABC goals – safety, cost-effective, sustainable, and has long cycle life

Relevance

- Transition new high energy battery chemistries invented in research laboratories to industrial production through independent validation and analysis in prototype cell formats.
  - xx3450 & xx6395 pouch cells; ranging from 20 to 3,000 mAh capacity.

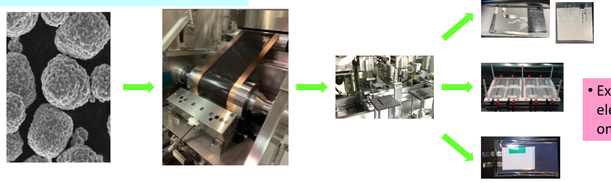
4 mAh Coin Cells → x100 → **400 mAh CAMP Zone** → x100 → 40 Ah PHEV/EV

- Researchers are often not able to provide the quantities of novel materials needed to make a full-size EV cell to demonstrate the merits of their discoveries. The CAMP Facility is specifically designed to explore new materials with quantities as small as 50 grams for active materials, and even less for electrode/electrolyte additives.

Approach

- Researchers submit materials with promising energy density
- Small hand-coated electrodes are made
- Coin cells are made and tested

- Larger material samples are obtained (MERF, partnerships, etc.)
- Longer lengths of electrode are made from scaled materials
- Pouch cells are made and tested



- Extensive diagnostics & electrochemical modeling on promising technologies

Progress

Multi-functional Coater

Demonstrated High Quality Coatings During Factory Acceptance Test

≥3 mAh/cm² at 0.5 m/min using the slot die coating head

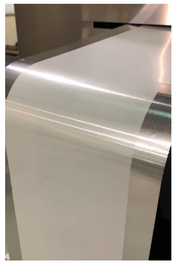
Verified functionality of:

- Interchangeable coating heads
- IR drying system
- Corona treatment
- Progressive cavity pump

Graphite slurry on copper foil

Al_2O_3 w/ PVDF on substrate

Uniform thin coatings using the gravure coating head.



Progress

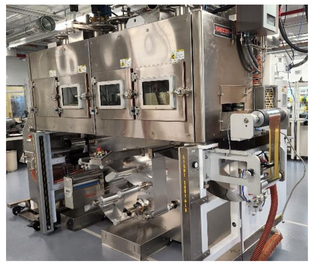
Multi-functional Coater Installed in Dry Room

Advanced interchangeable coating head system

Coating system greatly enhances adaptability for coating various materials.

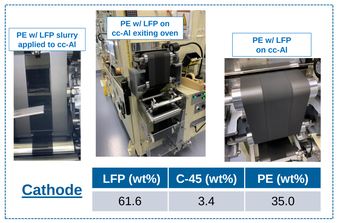
- Hybrid ceramic polymer electrolyte composite membrane
- Promising Next-Gen anodes and cathodes
- Solid-state electrolyte materials
- Traditional energy storage materials

FRONTIER



Electrode-Ceramic Structure Coatings

Produced >10 meters of electrode-ceramic films (1 to 3 mAh/cm²) using roll-to-roll Coater

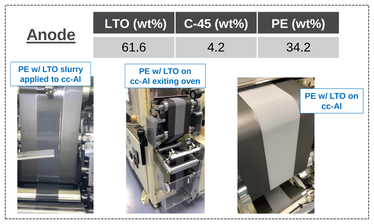


Cathode	LFP (wt%)	C-45 (wt%)	PE (wt%)
	61.6	3.4	35.0

Polymer electrolyte (PE)

	wt.%
PEGDA	40
LiTFSI	30
GN	30

Anode	LTO (wt%)	C-45 (wt%)	PE (wt%)
	61.6	4.2	34.2



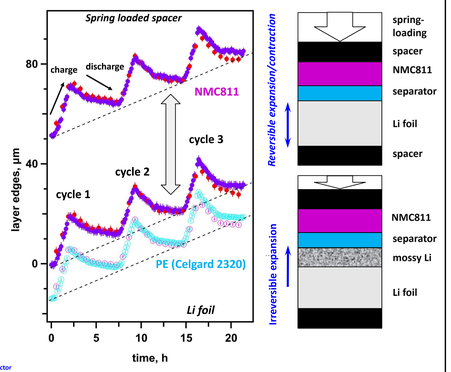
- AIBN added to the PE (initiator)
- Obtained well dispersed slurries with PE (diluted with NMP)
- Uniform films were applied to the carbon-coated Al (cc-Al) foil via reverse comma coating method.
- Polymerization was initiated during 5-minute heat-treatment; final curing step was completed in a convection oven.

See **BAT028**

X-ray Methodologies to Quantify Electrode Expansion

Developed X-ray methodologies to quantify electrode expansion in NMC811/Li cells

- During charge Li^+ ions are deposited on the Li, which expands and pushes the NMC811 cathode against the spring.
- During discharge, Li^+ ions are stripped from Li, releasing pressure on the spring.
- NMC811 and PE edges move together indicating that the separator is not compressed. The movement is solely because of expansion and contraction of the Li metal.



The irreversible expansion (drift) is 11.3 µm per cycle, or 34 µm for 3 cycles!

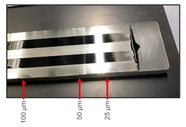
Progress

Materials for Diversifying Supply Chains and Increasing Sustainability

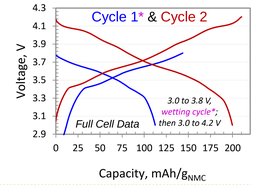
$LiNi_{0.90}Mn_{0.05}Co_{0.05}O_2$ (MERF & RNGC)

- Produced high quality slurry dispersion using high pH LNO-based oxide powder by mitigating gelation using slow order of addition process and temperature control
- Evaluated in 1.5 Ah pouch cells.

see **BAT167, BAT251, BAT252, BAT253**

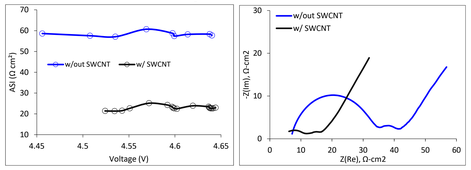


1.0 M $LiPF_6$ + 0.05M LiDFP in EC:EMC (1:9 w/w)



$LiMn_{1.5}Ni_{0.5}O_4$ (commercial)

Full Cell Impedance Performance



- 5V spinel electrodes with single wall carbon nanotubes (SWCNT) show lower cell impedance

see **BAT252**

~60% Mn, Co-free baseline powder for Earth-Abundant Cathode Active Materials (EaCAM)

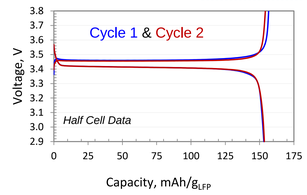
84 wt% LMR-NM
8 wt% Timcal C-45
8 wt% Solvay 5130 PVDF Binder
Coating Thickness: 54 µm
Total Coating Loading: 11.15 mg/cm²
Total Coating Density: 2.06 g/cm³
Areal Capacity: 2.19 mAh/cm²
[234 mAh/g; 3.0 to 4.5 V vs. Li/Li⁺]

see **BAT251**

$LiFePO_4$ (MERF) see **BAT470**

90 wt% LFP (made by MERF)
5 wt% Timcal C-45
5 wt% Solvay 5130 PVDF Binder
Coating Thickness: 94 µm
Total Coating Loading: 18.88 mg/cm²
Total Coating Density: 2.01 g/cm³
Areal Capacity: 2.61 mAh/cm²
Made by CAMP Facility

LFP powder prepared via hydrothermal process



- 30 mAh pouch cells (LFP//Gr) assembled and testing still in progress

Summary

- Developed methods to coat electrode-ceramic structure coating with roll-to-roll reverse comma coater in the dry room and produced >10 meters of these advanced films with loading targets ranging from 1 to 3 mAh/cm².
- Installed the multifunctional coater in the CAMP Facility dry room.
- Studied X-ray methodologies to quantify electrode expansion in NMC811/Li cells.
- Provided advanced prototype electrodes in the Electrode Library by producing >100 meters of anodes and cathodes (baseline and novel materials) in support of various DOE battery programs.

1,807 sheets (FY21) **923 sheets (FY22 as of April 2022)**

- Produced high quality electrodes using LiNi0.90Mn0.05Co0.05O2 powder by mitigating gelation and produced 1.5 Ah pouch cells.
- Produced electrodes using powders relevant to domestic supply chain and environmental sustainability, provided by RNGC (LMR-NM) and MERF (LFP).
- Supplied numerous experimental electrodes and cells to DOE programs.

247 cells (FY21) **146 cells (FY22 as of April 2022)**

Acknowledgment:

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